AD-A039136

FTD-ID(RS)I-1230-76

1 NW

FOREIGN TECHNOLOGY DIVISION

FUNCTION-DETERMINING CHARACTERISTIC VARIABLES FOR DETERMINATION OF THE DAMAGE LIMIT IN THE EXAMPLE OF RADIAL WAVE GASKETS

by

U. Voigt

Approved for public release;
distribution unlimited.

FTD- ID(RS)I-1230-76

EDITED TRANSLATION

FTD-ID(RS)I-1230-76 18 October 1976

FTD-76-C-001035

CST75099437

FUNCTION-DETERMINING CHARACTERISTIC VARIABLES FOR DETERMINATION OF THE DAMAGE LIMIT IN THE EXAMPLE OF RADIAL WAVE GASKETS

By: U. Voigt

English pages: 9

Source: V. Internationale Dichtungstagung, Dresden, Vol 1, 22-24 April 1974, PP. 55-64.

Country of origin: East Germany

Translated by: LINGUISTIC SYSTEMS, INC.
F33657-76-D-0389
Charles Funk

Requester: ASD/ETIL

Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

Function-Determining Characteristic Variables for Determination of the Damage Limit in the Example of Radial Wave Gaskets U. Voigt

According to TGL 80-22278 [1], the damage limit is defined as a characteristic value to distinguish serviceability and damage, wherein serviceability is understood as the capacity to perform a predetermined function within acceptable limits of quality and economy.

For investigation of the serviceability and for determination of damage limits, the value of the radial force at a nominal diameter, reported in the gasket industry, the spring washer constants used, and knowledge of the geometry of the packing washer are not sufficient, but the entire viscoelastic condition of the packing configuration (packing washer, shaft and spring washer) must be characterized. In the process, such characteristic variables of the packing configuration should be chosen, as are easily accessible to the measurement technology and provide a direct indication of the fulfillment of the gasket's function. The methods of investigating the function-determining values must additionally be applicable to the development of suitable gasket configurations and for a quality control system for mass production.

Through controlled experimentation and modelling treatments, the following characteristic values have been derived for radial wave gaskets:

I Function-determining characteristic values from the radial elastic expansion of the relieved gasket surface after the wave recedes from the gasket ring (Figure 1)

1. The spontaneous elastic recovery coefficient γ_e, or the relationship of the elastic deformation component to the total deformation γ_o; γ_o reflects the difference between the wave radius and the packing washer radius.

2. The deformation coefficient $\varepsilon_{rec.}$: If the relief deformation component γ_e is not determined at $t \approx 0$, but, for example, over

15 minutes, a deformation coefficient $\varepsilon_{rec.}$ is derived according to the following formula:

$$\varepsilon_{rec.} = d_1 - d_o / d_1 \cdot 100\ [\%] \text{, where} \quad (1)$$

d_o = packing washer diameter after recovery (measurement over 15 min.) and

d_1 = wave diameter.

3. Retardation time T' is the time required for the deformation to approach the final value in response to the elastic aftereffects on the elastic portion of γ_r.

The motion of recovery after sudden separation of the coupling ($t \approx 0$) can be recorded by a film camera capable of about 100 exposures per second. By simultaneously filming a fixed reference axle for the packing washer at a known difference between wave and packing washer diameters, the deformation coefficients γ_e and γ_r can be determined simply from measurement of lengths in the projection of the developed films. The retardation time T' is established by projecting the tangent to the curve of the elastic aftereffect and determining the point of intersection with the time axis.

II Function-determining characteristic values from the radial force/deformation relationship at a constant radial velocity of deformation

In a manner analogous to the motion of recovery, the packing washer configuration is related to the measurement of radial forces if there is an expansion at $t \approx 0$ equal to the elastic deformation component, and the subsequent extension proceeds exponentially. This elastic motion can be represented by a 3-parameter viscoelastic model, consisting of a series conjunction of a spring with a Voigt model. The use of this mechanical oscillator representation of the differential equation describing the packing washer configuration:

$$\frac{d\sigma}{dt} = E_1 \cdot \frac{d\gamma}{dt} + \frac{\gamma \cdot E_M - \sigma}{T^*} \qquad (2)$$

on the ring gasket with

$$v_o = \frac{r_{max} - r_{min}}{t} = \frac{\Delta r}{t} \quad \text{and} \qquad (3)$$

$$\frac{d\gamma}{dt} = \frac{d}{dt}\left(\frac{\Delta r}{r_{min}}\right) = \frac{v_o}{r_{min}} = \text{constant} \qquad (4)$$

yields, as the differential equation of the packing washer model with deformation at a constant radial velocity v_o:

$$\frac{d\sigma}{dt} = E_1 \cdot \frac{v_o}{r_{min}} - \frac{\sigma - \gamma(t) \cdot E_M}{T^*} \quad . \qquad (5)$$

The general solution of this differential equation (5) with $t = \delta \cdot r_{min}/v_o$ substituted as the time of trial yields the radial pressure/extension behavior of the packing washer model:

$$\sigma(\gamma) = E_M \cdot \gamma + (E_1 - E_M) \cdot T^* \cdot \frac{v_o}{r_{min}} \cdot e^{-t/T^*} \qquad (6)$$

which is proportional to the radial force/deformation behavior of the radial wave ring gasket (3). The curve of equation (6) is graphically represented in Figure 2, and shows that the radial force/deflection curve is dependent on the radial velocity of deformation v_o. At large trial times and low deformation velocity, the damping of the packing washer construction does not come into effect. According to the model, a constant pressure value $\sigma = E_M \cdot \gamma$ arises. Relief occurs as described due to hysteresis. The following function-determining characteristic values result from this relationship as a model of the packing washer configuration:

1. Radial force/deformation curve and its slope (so-called ring gasket characteristic curve)

The slope is derived by differentiating the pressure/

extension curve (equation 6) with respect to the extension γ. This value is proportional to the slope of the radial force/deformation curve, designated k (Figure 3).

In recording the ring gasket characteristic curve, it is to be noted that it is dependent on the radial propagation velocity.

2. From the radial force/deformation curve, the single radial force value at a nominal diameter presently given by the ring gasket industry can also be derived.

3. The surface area of the hysteresis loop represented in Figure 2 is a measure of the damping in the packing washer configuration. An elastic efficiency coefficient in % can be derived η_{el} as the quotient between the work expended in expansion and the work released in the recovery, multiplied by 100:

$$\eta_{el} = \frac{W_R}{W_A} \cdot 100 \; [\%] , \qquad (9)$$

where W_A = the work expended in loading and W_R = the work released in relief.

4. Further, a so-called radial effective spring constant R_M^* can be derived as a characteristic value for the packing washer configuration. It can be determined by static measurement of the specific radial force by the formula below, where the deformation γ is to be entered in dimensionless form: $\gamma = \Delta r/r$.

For the seal gap width, if this is not accessible to the measurement technology, the sleeve width b_1 can be entered as the model width. The effective spring constant E_M^* of the packing washer configuration is then the quotient between the specific radial force q and the product of the dimensionless deformation γ and the model width b_1:

$$E_M^* = \frac{q}{\cdot b_1} \quad [kp/cm^2]. \qquad (10)$$

Thus for the investigation of radially-acting elastic ring gaskets, seven characteristic values are available:

-elastic recovery coefficient γ_e

-deformation component ε_{rec} in measurements during 15 minutes

-retardation time T'

-radial force/deformation curve and its slope (ring gasket characteristic curve and spring constant)

-radial force at a nominal diameter

-area of the hysteresis loop or elastic efficiency coefficient η_{el}

-effective spring constant E_M^*.

Evaluation of the individual characteristic values is to be made in particular on the basis of their ability to give information concerning fulfillment of the sealing function and the expense of the measurement technology of their determination. In the case of gasket assemblies for which knowledge of the friction loss is required, or the case of gasket assemblies sealing against pressure, the radial force/deformation curves are of interest. In certain oscillation problems, on the other hand, recording the motion of recovery can be of advantage for the most precise estimation of the elastic conditions.

In the treatment of the damage limit problem, the deformation component after recovery ε_{rec}, for example, was determined as a function of the aging time in an oil bath at t=80° C according to equation (1), and the development of the ring gasket characteristic curves was determined for six RWD 70 x 100 x 10 ring gaskets with a running time of over 5400 hours duration [3].

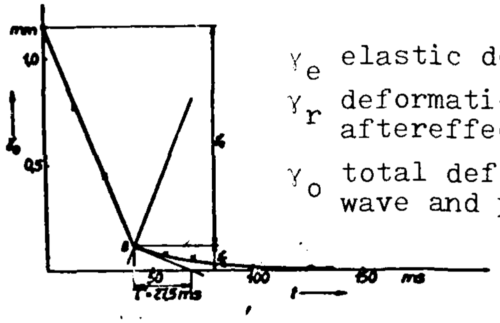
The results are shown in Figures 4 and 5. The deformation component ε_{rec} and with it the elastic condition decline as a logarithmic function of the period of aging in the oil bath. The same result, which is primarily due to the WS 1.018 material, is revealed in the characteristic curve field of Figure 5, in which the packing washer configuration stiffens as a function of changes due to the running time, as is revealed in the radial force gradient at a nominal diameter by an increase in the gradient of the spring constant at the beginning of the expansion, and by cracking in the perimeter of the packing washer after 5400 hours running time.

These experimental results show in particular that the ring gasket characteristic curve determined by the core measurement principle is well suited for a quality control system for mass production.

Besides these function-determining characteristic values, the following are to be added for radially-acting viscoelastic wave gaskets: The relaxation time T^*, as the time for the radial pressure or radial force to be reduced to the elastic portion of the total pressure or force. From the dynamic relationship of the gasket assembly are derived the phase shift angle α between the initiation of deformation by the excentrically travelling wave and the radial pressure in the packing configuration, the area of the dynamic hysteresis loop and the dynamic spring constant. These characteristic values are also theoretically derived and experimentally investigated in the dissertation of reference [3] "Methods to determine damage limits in radial wave gaskets." However, based on the present state of the measurement technology, they are at present meaningful only for research and development.

Symbols List

Symbol	Units	Meaning
b_1	mm	Model width (sleeve width)
d	mm	Wave diameter
d_o	mm	Packing washer diameter after recovery
d_1	mm	Core bar diameter
E_1, E_3	kp/cm²	Elasticity module of the 3-parameter model
E_M	kp/cm²	Effective elasticity module of the 3-parameter model
E_M^*	kp/cm²	Effective spring constant of the packing washer configuration
F_R	kp	Total radial force of the ring gasket
q	kp/cm	Specific radial force
k	kp/mm	Slope of the radial force/deformation curve (Spring constant of the ring gasket)
N		Sample size
r	mm	Wave radius
v_o	cm/s	Deformation velocity
t_A	h	Modifying hours in oil bath
ε		Deformation (expansion)
γ_o	mm	Total packing washer deformation (difference between packing washer and wave radii)
γ_e	mm	Ideal elastic packing washer deformation
γ_r	mm	Deformation corresponding to elastic aftereffect
ε_{rec}	%	Deformation component after recovery
η_{el}	%	Elastic efficiency coefficient of the packing washer configuration
σ	kp/cm²	Radial pressure of the packing washer
T^*	s	Relaxation time of the packing washer configuration
T'	s	Retardation time of the packing washer configuration



γ_e elastic deformation component

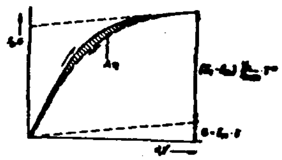
γ_r deformation component due to elastic aftereffect

γ_o total deformation (difference between wave and packing washer radii)

Figure 1: Motion of recovery of the packing washer of an RWD 70 x 100 x 10 WS 1.018

The differential equation $\frac{d\delta}{dt}=E_1\frac{d\gamma}{dt}+\frac{\gamma E_M-\delta}{T^*}$ of the packing washer calculated with $\frac{d\gamma}{dt}=\frac{d}{dt}(\gamma)=\frac{d}{dt}\left(\frac{\Delta r}{r_{min}}\right)=\frac{v_o}{r_{min}}$ yields the pressure/extension relationship where v_o is constant: $\delta(\gamma)=E_M\cdot\gamma+(E_1-E_M)T^*\cdot\frac{v_o}{r_{min}}\cdot e^{-t/T^*}$

where: trial time $t=\frac{\gamma-r_{min}}{v_o}$,



relaxation time $T^*=\frac{\eta_{el}}{E_1+E_3}$, r_{min}-exit radius of the core at t=0 in the region of the nominal diameter radial velocity of deformation of the packing washer: $v_o=\frac{\Delta r}{t}$. area of the hysteresis loop: A_q

Figure 2: Pressure/deformation relationship of the packing washer model

$$\left|\frac{d\sigma}{d\gamma}\right|_{v_o=const.} = E_n+(E_1-E_n)\cdot e^{-t/T^*} \qquad (7)$$

$$K_{v_o=const.}=\left|\frac{\Delta F_r}{\Delta d}\right|_{v_o=const.}\approx\left|\frac{d\sigma}{d\gamma}\right|_{v_o=const.}$$

Figure 3: Proportionality relation between the spring constant k and $d\sigma/d\gamma$

1 RWD 70 x 100 x 10 WS 1.018
2 Altering medium: 125 oil 80° C
3 Packing washer temp: 20° C
4 Determination of ε_{rec} during 15 min. recovery
5 Determining equation:

$$_{rec} = \frac{d_{1,2} - d_0}{d_{1,2}} \cdot 100 \ [\%]$$

6 d_0-diameter after recovery
7 $d_{1,2}$-core bar diameter

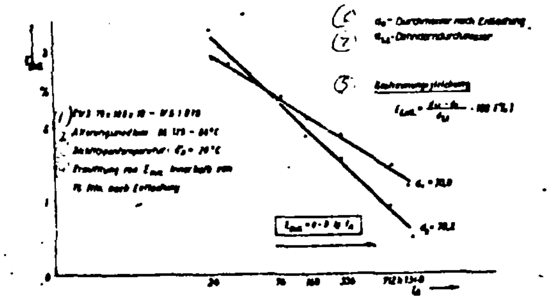


Figure 4: Deformation component after recovery ε_{rec} as a function of the altering time t_A
Key is illegible

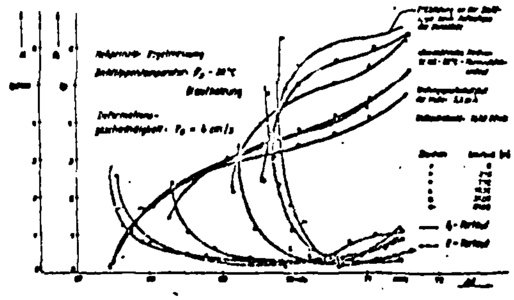


Figure 5: Field of characteristic curves of the long term experiment RWD 70 x 100 x 10 WS 1.018

Bibliography

[1] TGL 80-22278 Basic concepts of agricultural maintenance.

[2] Nowaki, W., Theory of linear viscoelastic flow; Franz Deuticke Press, Vienna 1965.

[3] Voigt, U., Methods to determine damage limits in radial wave gaskets; Dissertation, Rostock University, Rostock 1973.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: FTD-ID(RS)I-1230-76 ✓	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): FUNCTION-DETERMINING CHARACTERISTIC VARIABLES FOR DETERMINATION OF THE DAMAGE LIMIT IN THE EXAMPLE OF RADIAL WAVE GASKETS	5. TYPE OF REPORT & PERIOD COVERED: Translation
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): U. Voigt	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Foreign Technology Division, Air Force Systems Command, U. S. Air Force	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE: 22-24 April 1974
	13. NUMBER OF PAGES: 9
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

13

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE	ORGANIZATION		MICROFICHE
A205	DMATC	1	E053	AF/INAKA	1
A210	DMAAC	2	E017	AF/RDQLR-W	1
B344	DIA/DS-4C	8	E404	AEDC	1
C043	USAMIIA	1	E408	AFWL	1
C509	BALLISTIC RES LABS	1	E410	ADTC	1
C510	AIR MOBILITY R&D LAB/FIO	1	E413	ESD	2
C513	PICATINNY ARSENAL	1		FTD	
C535	AVIATION SYS COMD	1		CCN	1
C557	USAIIC	1		ETID	3
C591	FSTC	5		NIA/PHS	1
C619	MIA REDSTONE	1		NICD	5
D008	NISC	1			
H300	USAICE (USAREUR)	1			
P005	ERDA	2			
P055	CIA/CRS/ADD/SD	1			
NAVORDSTA (50L)		1			
NAVWPNSCEN (Code 121)		1			
NASA/KSI		1			
544 IES/RDPO		1			
AFIT/LD		1			